

관상동맥 완전폐쇄 병변을 보이는 환자에서 측부순환 발달 및 측부순환의 임상적 영향

이상현¹ · 정명호^{1,2} · 주신배¹ · 박형욱¹ · 강경태¹ · 김남호¹ · 김건형¹
이승욱¹ · 조장현¹ · 안영근¹ · 조정관^{1,2} · 박종춘^{1,2} · 강정채^{1,2}

The Development of Collateral Circulation in Patients with Total Occlusion of Coronary Artery and its Clinical Significance

Sang Hyun Lee, MD¹, Myung Ho Jeong, MD^{1,2}, Shin Bae Joo, MD¹, Kyung Tae Kang, MD¹,
Hyung Wook Park, MD¹, Nam Ho Kim, MD¹, Kun Hyung Kim, MD¹, Seung Uk Lee, MD¹,
Jang Hyun Cho, MD¹, Young Keun Ahn, MD¹, Jeong Gwan Cho, MD^{1,2},
Jong Chun Park, MD^{1,2} and Jung Chae Kang, MD^{1,2}

¹The Heart Center of Chonnam University Hospital, ²The Research Institute of Medical Sciences,
Chonnam National University, Kwangju, Korea

ABSTRACT

Background and Objectives : Coronary collateral circulation is known to have beneficial effects in patients with angina pectoris and myocardial infarction. The purpose of this study is to determine the predictors of collateral vessels development, the pathways of collateral circulation and the changes in collateral flow after coronary intervention and its functional significance in patients with total occlusion. **Materials and Methods :** One hundred thirty five patients who underwent coronary angiogram between Jan '97 and Dec '97 in Chonnam University Hospital (out of 3,264 cases) had total occlusion of one coronary artery were classified into two groups ; angina pectoris (Group I : 50 M, 19 F, 62.4 ± 11.0 years) and acute myocardial infarction (Group II : 47 M, 19 F, 62.0 ± 9.5 years). **Results :** Among 135 patients, 123 patients had collateral circulation. Collaterals were more frequently observed and better developed (grade 2 or 3) in Group I than Group II. Proximal and ostial lesions were associated with well developed collaterals. Collateral circulation was more frequently observed and well developed in proportion to the duration of angina in Group I. In 123 patients with collateral circulation, 247 collateral circulations were observed. Right coronary artery (RCA) and Left circumflex coronary artery (LCX) were more frequent recipient arteries than left anterior descending coronary artery (LAD) (RCA : 2.20 ± 1.02, LCX : 1.88 ± 0.94, LAD : 1.29 ± 0.8 respectively, RCA vs. LAD : $p < 0.001$, LCX vs. LAD : $p = 0.014$). Coronary interventions were performed in 50 out of 135 patients, collateral flow of Group II decreased much more than Group I after intervention (Group I : 5/14, Group II : 24/36, $p = 0.046$). The wall motion score was lower in patients with well developed than poorly developed collaterals (20.7 ± 4.91 vs. 23.7 ± 6.22, $p = 0.015$). **Conclusion :** Proximal or ostial lesion and duration of

: 1999 8 24

: 2000 2 17

: , 501 - 757 1 8

: (062) 220 - 6243 · : (062) 228 - 7174

E - mail : myungho@chollian.net

KEY WORDS : Collateral · Angina · Myocardial infarction.

28)

서론

가 가

29 - 31)

,

, ,

3) Schaper³⁾

(recruit -

ent of preexisting collapsed collaterals),

(neoangiogenesis) , Schu -

a her³²⁾ basic fibro -

last growth factor - 1(bFGF - 1)

24 , , 24

29)33)34)

가

4)

가

5)6) , 7)

(myocardial contrast echocardiography)⁸⁾⁹⁾

10)

가 가

11)12)

대상 및 방법

13 - 26)

가 1997 1 1997 12

20 200 µm 3,264

135

261

(ostial lesion) ,
 가 50% (tan -
 em lesion) 가
 (I , 50 , 19 ; 62.4±11.0) 가
 (II , 47 , 19 ;
 62.0±9.5) (Table 1), (ischemic burden)
 .
 , 2 , 1
 0.1 mV ST , 1 6 6
 가 2가
 Judkin 1 , 1 7
 , 7
 , Rentrop Cohen
 38) 0 , 1
 가 .
 American Society of , 2
 Echocardiography³⁵⁾³⁶⁾ 16 , 3
 1 5
 1, 2, 2 , 1
 3, 4 가
 5
 (wall motion score)
 area - length method³⁷⁾
 .
 ,
 Chi - square test,
 Student t - test ,
 One - way ANOVA test p
 0.05 가

Table 1. Clinical characteristics and echocardiographic findings in patients with angina (Group I) and acute myocardial infarction (Group II)

| | Group I (n = 69) | Group II (n = 66) | Total (n = 135) |
|---|-----------------------|----------------------|--------------------|
| Age (years) | 62.4±11.0 | 62.0± 9.5 | 62.2±10.8 |
| Sex (M : F) | 50 : 19 | 47 : 19 | 97 : 38 |
| Angina duration | 26.6± 4.2 (months) | 2.8± 1.8 (day) | |
| Q wave myocardial infarction (Yes : No) | 8 : 5 | 7 : 32 | 15 : 37 |
| Ejection fraction (%) | 55.9±14.0 | 51.1±13.8 | 53.3±14.0 |
| Wall motion score | 19.2± 4.3 | 4.5± 5.6* | 21.9± 5.6 |

*p = 0.007

결 과

협심증 환자군과 급성심근경색 환자군간의 비교

(I)

(II)

Table 2. Comparison of angiographic characteristics between patients with angina (Group I) and acute myocardial infarction (Group II)

| | Group I (n = 69) | Group II (n = 66) | Total (n = 135) |
|-------------------------|---------------------|----------------------|--------------------|
| Occluded artery | | | |
| LAD (%) | 19 (27.5) | 25 (37.8) | 44 (32.6) |
| LCX (%) | 26 (37.7) | 15 (22.8) | 41 (30.4) |
| RCA (%) | 24 (34.8) | 26 (39.4) | 50 (37.0) |
| Diseased vessel numbers | | | |
| 1 vessels (%) | 28 (40.6) | 13 (19.7) | 41 (30.3) |
| 2 vessels (%) | 18 (26.1) | 25 (37.8) | 43 (31.9) |
| 3 vessels (%) | 23 (33.3) | 28 (42.5) | 51 (37.8) |
| Proximal lesion | 32 (46.4) | 40 (60.6) | 72 (53.3) |
| Collateral grade | | | |
| Grade 0 (%) | 4 (5.8) | 8 (12.1) | 12 (8.9) |
| Grade 1 (%) | 15 (21.7) | 26 (39.4) | 41 (30.3) |
| Grade 2 (%) | 26 (37.7) | 27 (40.9) | 53 (39.3) |
| Grade 3 (%) | 24 (34.8) | 5 (7.6) | 29 (21.5) |
| Lesion characteristics | | | |
| Ostial lesion (%) | 11 (15.9) | 14 (21.2) | 25 (18.5) |
| Bifurcation (%) | 27 (39.1) | 24 (36.4) | 51 (37.8) |
| Tandem lesion (%) | 23 (33.3) | 15 (22.8) | 38 (28.1) |
| Aneurysm (%) | 16 (23.2) | 26 (39.4) | 7 (5.2) |

LAD : left anterior descending artery, LCX : left circumflex artery, RCA : right coronary artery

(Table 1, 2).

(I : $55.9 \pm 14.0\%$, II

$51.1 \pm 13.8\%$, $p = \text{NS}$)

가

($19.2 \pm$

4.30 vs. 24.50 ± 5.55 , $p = 0.007$, Table 1).

I Grade 1 15 , Grade 2가 26

, Grade 3 24 94.2%(65/69)

, 72.5%(50/69) Grade 2

. II Grade 1

26 , Grade 2가 27 , Grade 3 5 84.9%

(56/66) , 48.5%(32/66)

Grade 2 I

Table 3. Collateral grade in patients with angina (Group I) and acute myocardial infarction (Group II)

| | Group I | Group II | Total |
|--------------|-----------------|-----------------|-----------------|
| Collateral*† | | | |
| Grade 0 (%) | 4 (5.8) | 8 (12.1) | 12 (8.9) |
| Grade 1 (%) | 15 (21.7) | 26 (39.4) | 41 (30.4) |
| Grade 2 (%) | 26 (37.7) | 27 (40.9) | 53 (39.3) |
| Grade 3 (%) | 24 (34.8) | 5 (7.6) | 29 (21.4) |
| Mean† | 2.01 ± 0.90 | 1.44 ± 0.80 | 1.73 ± 0.90 |
| Total | 69 | 66 | 135 |

More frequent (* $p = 0.001$) and more well ($^{\dagger}p = 0.02$) developed collateral circulation (equal or over the grade 2) was observed in Group I, $^{\dagger}p = 0.001$: Mean value of collateral grade is higher in Group I

Table 4. Lesion characteristics and left ventricular function parameters according to collateral grade

| | Collateral grade | | | | Total |
|-----------------------|------------------|-----------|--------------------------|-----------|-----------------|
| | 0 | 1 | 2 | 3 | |
| Proximal lesion* | | | | | |
| Yes (%) | 4 (5.6) | 16 (22.2) | 35 (48.6) | 17 (23.6) | 72 |
| No (%) | 8 (12.7) | 25 (39.7) | 18 (28.6) | 12 (19.0) | 63 |
| Total (%) | 12 (8.9) | 41 (30.3) | 53 (39.3) | 29 (21.5) | 135 |
| Ostial lesion† | | | | | |
| Yes (%) | 0 | 3 (12.0) | 12 (48.0) | 10 (40.0) | 25 |
| No (%) | 12 (10.9) | 38 (34.5) | 41 (37.3) | 19 (17.3) | 110 |
| Total (%) | 12 (8.9) | 41 (30.3) | 53 (39.3) | 29 (21.5) | 135 |
| Ejection fraction (%) | 50.6 ± 13.1 | | 55.1 ± 14.4 | | 53.3 ± 14.0 |
| Wall motion score | 23.8 ± 6.2 | | $20.8 \pm 5.0^{\dagger}$ | | 21.9 ± 5.6 |

*More frequent ($p = 0.028$) and well developed ($p = 0.003$) collateral flow was observed in patients with proximal lesion, † More frequent ($p = 0.009$) and well developed ($p = 0.002$) collateral flow in patients with ostial lesion, ‡ Lower wall motion score ($p = 0.015$) was observed in patients with good collateral

($p=0.001$)가
($p=0.02$) ,
(I : 2.0 ± 0.90 , II : 1.4 ± 0.80 , p
=0.001, Table 3).
72 68
(94.4%)
63 55 (87.3%)
($p=$
0.028), Grade 2
72 52 (72.2%),

Table 5. Collateral flow grade according to the duration of angina in patients with angina pectoris (upper), myocardial infarction (lower)

| Angina pectoris | | | | |
|-------------------------|-----------|------------|-----------|--|
| Duration Grade | < 1 ms | 1 and 6 ms | > 6ms | |
| 0 or 1 (%) | 5 (26.3) | 4 (21.1) | 10 (52.6) | |
| 2 or 3 (%)* | 1 (2.0) | 6 (12.0) | 43 (86.0) | |
| Myocardial infarction | | | | |
| Duration Grade | < 1 ds | 2 and 7 ds | > 7ds | |
| 0 or 1 (%) | 23 (67.6) | 8 (23.6) | 3 (8.8) | |
| 2 or 3 (%) [†] | 10 (31.3) | 14 (43.7) | 8 (25.0) | |

* $p=0.02$, [†] $p=0.01$

Table 6. Lesion characteristics and left ventricular function according to the presence of well developed collateral circulation in patients with angina

| | Collateral grade | | Total |
|----------------------------|------------------|------------|-------|
| | 0 or 1 | 2 or 3 | |
| Proximal lesion* | | | |
| Yes (%) | 4 (12.5) | 28 (87.5) | 32 |
| No (%) | 15 (40.5) | 22 (59.5) | 37 |
| Total (%) | 19 (27.5) | 50 (72.5) | 69 |
| Ostial lesion [†] | | | |
| Yes (%) | 0 (0.0) | 11 (100.0) | 11 |
| No (%) | 39 (67.2) | 19 (32.7) | 58 |
| Total (%) | 39 (56.5) | 30 (43.5) | 69 |

Ejection fraction (%) 54.1 ± 13.5 56.9 ± 14.3 55.9 ± 14.0

Wall motion score 20.8 ± 4.5 $18.5 \pm 4.0^{\dagger}$ 19.2 ± 4.3

Well developed collateral circulation was observed in patients with proximal lesion (* $p=0.009$), ostial lesion ([†] $p=0.028$), [‡] $p=0.048$: Wall motion score are lower in patients with well developed collateral than in poor collateral circulation

63 30 (47.6%)
($p=0.009$).
25
(100%)
110 98 (89.1%)
($p=0.002$).
Grade 2 Grade 1
가 (20.8 ± 5.0 vs 23.8 ± 6.2 , $p=0.015$)
(55.1 ± 14.4 vs 50.6 ± 13.1 , $p=0.015$, Table 4).

협심증 환자군에서 비교

가 ,
($p=0.021$), (6 ms
vs 6 ms =43/53, 81.1% vs 9/16, 56.3%, $p=$
0.02).

Table 7. Lesion characteristics and left ventricular function between collateral flow in patients with acute myocardial infarction

| | Collateral grade | | Total |
|----------------------------|------------------|-----------|-------|
| | 0 or 1 | 2 or 3 | |
| Proximal lesion* | | | |
| Yes (%) | 16 (40.0) | 24 (60.0) | 40 |
| No (%) | 18 (69.2) | 8 (30.8) | 26 |
| Total (%) | 34 (51.5) | 32 (48.5) | 66 |
| Ostial lesion [†] | | | |
| Yes (%) | 3 (21.4) | 11 (78.6) | 14 |
| No (%) | 31 (59.6) | 21 (40.4) | 52 |
| Total (%) | 34 (51.5) | 32 (48.5) | 66 |

Ejection fraction (%) 48.4 ± 12.6 53.3 ± 14.6 51.1 ± 13.8

Wall motion score[‡] 25.7 ± 6.5 23.5 ± 4.5 24.5 ± 5.6

Well developed collateral circulation was observed in patients with proximal lesion (* $p=0.020$), ostial lesion ([†] $p=0.011$), [‡] $p=0.47$: Lower wall motion score was observed in patients with well developed collateral than in poor collateral circulation

Table 8. Left ventricular function and wall motion score according to occluded arteries

| | LAD | LCX or RCA |
|-----------------------|-----------------|--------------------------|
| Ejection fraction (%) | 44.6 ± 11.0 | $55.6 \pm 14.0^*$ |
| Wall motion score | 26.6 ± 5.8 | $23.1 \pm 5.0^{\dagger}$ |

* $p=0.008$, [†] $p=0.04$, LAD : left anterior descending artery, LCX : left circumflex artery, RCA : right coronary artery

가 ($p=0.035$, 0.045 , 0.025 , Table 5).

11 (11/11
, 100%) Grade 2
(19/58 , 32.8%)
($p=0.028$),

(28/32 , 87.5% vs 22/37 , 59.5%, $p=0.09$).

가
(56.9 ± 14.3 vs 54.1 ± 13.5 , $p=NS$)

가
(, 18.5 ± 4.0 vs 20.8 ± 4.5 , $p=0.048$,
Table 6).

급성심근경색 환자군에서 비교

가
가 2
(1
vs 2 =10/33, 30.3% vs 22/33, 66.7%,
 $p=0.01$, Table 5).

(, 10/12, 83.3% vs 16/37,
43.2%, $p=0.011$),

(, 24/40 , 60% vs 8/26 ,
30.8%, $p=0.020$).

(, 53.3 ± 14.6 vs $48.4 \pm$
 12.6 , $p=NS$) 가

(, 23.5 ± 4.5 vs 25.7
 ± 6.5 , $p=0.47$, Table 7).

(, 44.6
 ± 10.9 vs 55.6 ± 13.9 , $p=0.008$), 가

(, 26.6 ± 5.8 vs 23.1 ± 5.0 , $p=0.04$).

관상동맥 중재술후 측부순환의 변화

(
,) 3

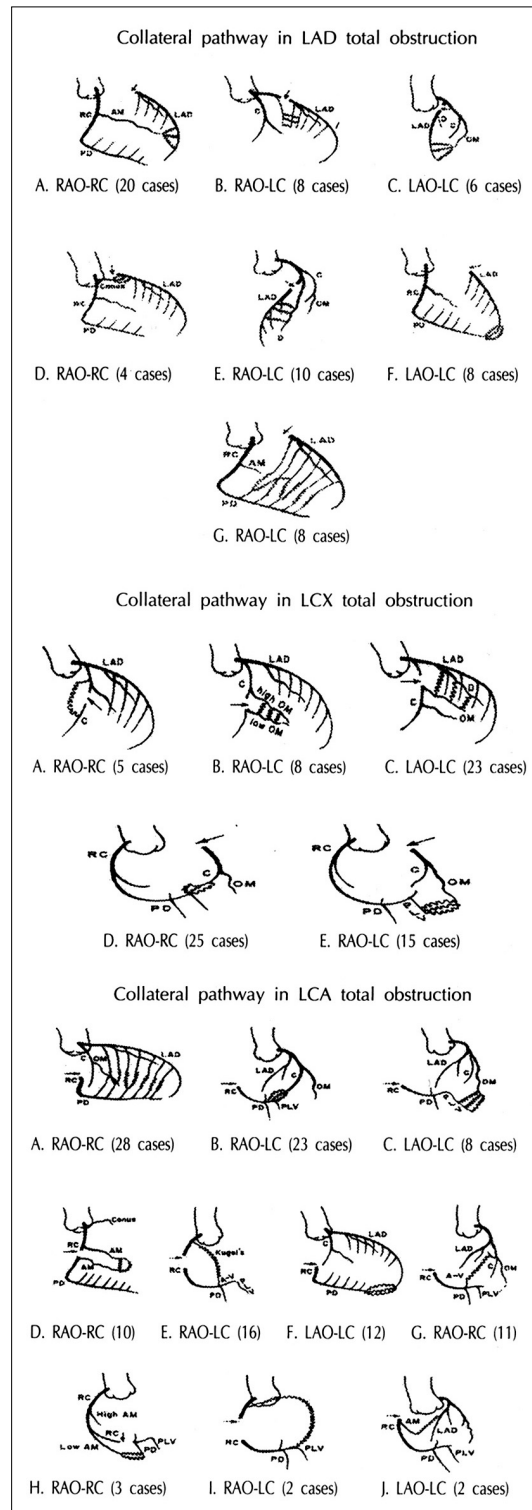


Fig. 1. Diagram of collateral pathway in 123 patients with total coronary artery occlusion.

50 , 가 82.8%(24/29 가 ⁴³⁾
) 57.1%(12/21)
 ($p=0.046$).

측부순환의 경로

123 247 가 가 가
 (supplier artery) . Rentrop ⁴⁴⁾ Cohen ³⁸⁾ 70%
 44 41 (93.2%) Kass ⁴⁵⁾ 80 90%
 18 ,
 6 , 40 가 ,
 41 38 (92.7%)
 36 ,
 40 가 (Fig. 1),
 50 49 (98%) 가
 42
 , 42 , 31 가
 2.20 ± 1.02, 1.88 ± 0.94, 가
 1.29 ± 0.81
 (, $p<0.001$, $p=0.014$).

고 찰

가 , Schaper ⁴⁶⁾
³⁹⁾ Piek ⁴⁰⁾
 2
 (response to injury phase)
 (vascular growth phase)
 가 가 (ischemic 4
 burden) 가 90% Fujita
 가 ⁴¹⁾⁽⁴²⁾ ⁴⁷⁾
 (ischemic myocardial mass) 가 Piek ⁴¹⁾
 (maturation) 3

가

가

가

(maturation)

가

가 . Sheehan ⁵⁰⁾

(compensatory hyperkinesia)

가

가

가 2

가

Levin ⁴⁸⁾

22가

가

가 ,

2/3가

Stadius ⁴⁹⁾

⁵¹⁾

Hamby ⁵²⁾

(myocardial 가 (supplier)

resistance)

Goldberg ⁵³⁾

가

Goldberg ⁵³⁾

가

Hamby ⁵²⁾

가

Stradius ⁴⁹⁾

가

가

가

가

1)4)14)

22 - 25)27)

본 연구의 제한점

가

- HT. *The role of collateral circulation in the various coronary syndromes.* *Circulation* 1979;59:1137-44.
- 2) Greenspan M, Iskandrian AS, Segal BL, Kimbris D, Bemis CE. *Complete occlusion of the left main coronary artery.* *Am Heart J* 1979;98:83-6.
- 3) Schaper W, Gorge G, Winkler B, Schaper J. *The collateral circulation of the heart.* *Prog Cardiovasc Dis* 1988;31: 57-77.
- 4) Jeong MH, Yang SJ, Gill GC, Park JH, Bom HS, Cho JG, et al. *The effect of collateral circulation on myocardial perfusion during PTCA in patients with angina pectoris.* *Korean Circulation J* 1994;24:943-53.
- 5) Helfant RH, Vokonas PS, Gorlin R. *Functional importance of the human coronary collateral circulation.* *N Engl J Med* 1971;284:1227-81.
- 6) Hansen JF. *Coronary collateral circulation: clinical significance and influence on survival in patients with coronary artery occlusion.* *Am Heart J* 1989;117:290-5.
- 7) Berger BC, Watson DD, Taylor GJ, Burwall LR, Martin RP, Beller GA. *Effect of coronary collateral circulation on regional myocardial perfusion assessed with quantitative thallium-201 scintigraphy.* *Am J Cardiol* 1980;46: 365-70.
- 8) Keller MW, Spotnitz WD, Matthew TL, Glasheen WP, Wastson DD, Kaul S. *Intraoperative assessment of regional myocardial perfusion using quantitative myocardial contrast echocardiography: an experimental evaluation.* *J Am Coll Cardiol* 1990;16:1267-79.
- 9) Reeder GS. *Contrast echocardiography and coronary collateral flow.* *J Am Coll Cardiol* 1990;16:1601-2.
- 10) Bonetti F, Margonato A, Maihac A, Carendente O, Cappelletti A, Ballarotto C, et al. *Coronary collateral reduce the duration of exercise-induced ischemia by allowing a faster recovery.* *Am Heart J* 1992;124:48-55.
- 11) Lesperance J, Bourassa MG, Biron P, Campeau L. *Aorta to coronary artery saphenous vein graft. Preoperative angiographic criteria for successful surgery.* *Am J Cardiol* 1972;30:459-65.
- 12) Rosch J, Dotter CT, Antonovic R, Bonchek L, Starr A. *Angiographic appraisal of distal vessel suitability or aortocoronary bypass surgery.* *Circulation* 1973;48:202-12.
- 13) Nohara R, Kambara H, Murakami K, Tamaki S, Kawai C. *Collateral function in early acute infarction.* *Am J Cardiol* 1983;52:955-9.
- 14) Rogers W, Hood WP, Mantle JA, Baxley WA, Kirklin JK, Zorn GL, et al. *Return of left ventricular function after reperfusion in patients with myocardial infarction: importance of subtotal stenosis or intact collaterals.* *Circulation* 1984;69:338-49.
- 15) Schwartz H, Leiboff RL, Katz RJ, Wasserman AG, Bren GB, Varghese PJ, et al. *Arteriographic predictors of spontaneous improvement in left ventricular function after myocardial infarction.* *Circulation* 1985;71:466-72.
- 16) Saito Y, Yasuno M, Ishida M, Suzuki K, Matoba Y, Emura M, et al. *Importance of coronary collaterals for restoration of left ventricular function after intracoronary thrombolysis.* *Am J Cardiol* 1985;55:1259-63.
- 17) Hirai T, Fujita M, Sasayama S, Ohno A, Yamanishi K, Nakajima H, et al. *Importance of coronary collateral circulation for kinetics for serum creatine kinase in acute myocardial infarction.* *Circulation* 1989;79:791-6.
- 18) Rentrop KP, Feit R, Sherman W, Stecy P, Hosat S, Cohen M, et al. *Late thrombolytic therapy preserves left ventricular function in patients with collateralized total coronary occlusion: primary end point findings of The second Mount Sinai-New York University Reperfusion Trial.* *J Am Coll Cardiol* 1989;14:58-64.
- 19) Habib GB, Heibig J, Forman SA, Brown BG, Roberts R, Terrin ML, et al. *Influence of coronary collateral vessels on myocardial infarct size in humans: result of phase I Thrombolysis in myocardial infarction (TIMI) Trials.* *Circulation* 1991;83:739-46.
- 20) Topol EJ, Ellis SG. *Coronary collaterals revisited: accessory pathway to myocardial preservation during infarction.* *Circulation* 1991;83:1084-6.
- 21) Hansen J. *Coronary collateral circulation: clinical significance and influence on survival in patients with coronary artery occlusion.* *Am Heart J* 1989;117:290-5.
- 22) Brush J, Brand DA, Acampora D, Goldman L, Cabin HS. *Relation of peak creatine kinase levels during myocardial infarction to presence or absence of previous manifestations of myocardial ischemia (angina pectoris or healed myocardial infarction).* *Am J Cardiol* 1988;62:534-7.
- 23) Miller R, Manson D, Sable A, Zelis R, Massumi R, Amsterdam E. *Determinations and functional significance of the coronary collateral circulation in patients with coronary artery disease (abstract).* *Am J Cardiol* 1972;29:281.
- 24) Schwartz H, Leihoff RH, Bren GB, Wasserman AG, Katz RJ, Varghese PJ, et al. *Temporal evolution of the human coronary collateral circulation after myocardial infarction.* *Am J Cardiol* 1984;4:1088-93.
- 25) Schwartz F, Flameng W, Ensslen R, Sesto M, Thormann J. *Effects of collaterals on left ventricular function at rest and during stress.* *Am Heart J* 1978;95:570-7.
- 26) Helfant R, Vokonas P, Gorlin R. *Functional importance of human collateral circulation.* *N Engl J Med* 1971;284: 1277-81.
- 27) Ha JW, Cho SY, Jang YS, Chung NS, Shim WH, Kim SS, et al. *Functional significance of collateral circulation in patients with total coronary occlusion.* *Korean Circulation J* 1993;23:522-32.
- 28) Marcus M. *The coronary circulation in health and disease.* New York: McGraw-Hill;1983. p.221-41.
- 29) Sasayama S, Fugita M. *Recent insights into coronary collateral circulation.* *Circulation* 1982;85:1197-204.
- 30) Greg D. *The natural history of coronary collateral development.* *Circ Res* 1974;35:335.
- 31) Hirzel H, Nelson H, Sonnenblick E, Kirk E. *Redistribution of collateral flow from necrotic to surviving myocardium following coronary occlusion in the dog.* *Circ Res* 1997; 39:214.
- 32) Schumacher P, Pecher BU. *Induction of neoangiogenesis in ischemic myocardium by human growth factor.* *Circulation* 1998;97:645-50.
- 33) Kass RW, Kottler MW, Yazdanfer S. *Stimulation of coronary collateral growth: current developments in angiogenesis and future clinical application.* *Am Heart J* 1992; 123:486-96.
- 34) Daisy FL, Mickey S, Matie S, Everett H, Sharmini R, Sally H, et al. *Effects of chronic systemic administration of basic fibroblast growth factor on collateral development in the canine heart.* *Circulation* 1995;91:145-53.

- 35) American Society of Echocardiography Committee on Standards. *Recommendations for quantification of the left ventricle by two dimensional echocardiography*. *Am J Soc Echocardiogr* 1989;2:358-67.
- 36) Quinones MA, Waggoner AD, Reduto JG, Young JB, Winter WL Jr, Ribeiro LG, et al. *A new simplified and accurate method for determining ejection fraction with two-dimensional echocardiography*. *Circulation* 1981;64:744-53.
- 37) Shiina A, Tajik AJ, Smith HC, Lengyel M. *Prognostic significance of regional wall motion abnormality in patients with prior myocardial infarction: a prospective correlative study of two dimensional echocardiography and angiography*. *Mayo Clin Proc* 1986;61:254-62.
- 38) Cohen M, Sherman W, Rentrop KP, Gorlin R. *Determinants of collateral filling observed during sudden controlled coronary artery occlusion in human subjects*. *J Am Coll Cardiol* 1989;13:297-303.
- 39) Scheel KW, Rodriguez RZ, Ingram LA. *Directional coronary collateral growth with chronic circumflex occlusion in the dog*. *Circ Res* 1977;40:384-90.
- 40) Piek JJ, Koolen JJ, Hoedemaker G, David GK, Visser CA, Dunning AJ. *Severity of single-vessel coronary arterial stenosis and duration angina as determinants of recruitable collateral vessels during balloon angioplasty occlusion*. *Am J Cardiol* 1991;67:13-7.
- 41) Piek JJ, van Liebergen R, Koch KT, Peters JG, David GK. *Clinical, angiographic and hemodynamic predictors of recruitable collateral flow assessed during balloon angioplasty coronary occlusion*. *J Am Coll Cardiol* 1997;29:275-82.
- 42) Piek JJ, Koolen JJ, Hoedemaker G, David GK, Visser CA, Dunning AJ. *Severity of single-vessel coronary arterial stenosis and duration of angina as determinants of recruitable collateral vessels during balloon angioplasty occlusion*. *Am J Cardiol* 1991;67:13-7.
- 43) Baroldi G. *Coronary stenosis: ischemic or nonischemic factor?* *Am H J* 1978;96:139-43.
- 44) Rentrop KP, Thornton JC, Feit F, Van Buskirk M. *Determinants and prospective potential of coronary arterial collaterals as assessed by an angioplasty model*. *Am J Cardiol* 1988;61:677-84.
- 45) Kass RW, Kotler MN, Yazdanfar S. *Stimulation of coronary collateral growth: current developments in angiogenesis and future clinical applications*. *Am Heart J* 1992;123:486-96.
- 46) Schaper W, Flameng W, Winkler B, Wussten B, Turrshmann W, Neugebauer G, et al. *Quantification of collateral resistance in acute and chronic experimental coronary occlusion in the dog*. *Circ Res* 1976;39:371-7.
- 47) Fujita M, Sakayama S, Ohno A, Yamanishi K, Araie E, Franklin D. *Importance of myocardial ischemia for collateral development in conscious dogs*. *Intern J Cardiol* 1990;27:179-86.
- 48) Levin DC. *Pathways and functional significance of the coronary collateral circulation*. *Circulation* 1974;50:831-7.
- 49) Stadius ML, Maynard C, Fritz JK, Davis K, Ritchie JL, Sheehan F, et al. *Coronary anatomy and left ventricular function in the first 12 hours of acute myocardial infarction: the Western Washington Randomized Intracoronary Streptokinase Trial*. *Circulation* 1985;72:292-301.
- 50) Sheehan F, Braunwald E, Canner P, Dodge HT, Gore J, Natt PV, et al. *The effect of intravenous thrombolytic therapy on left ventricular function: a report on tissue-type plasminogen activator and streptokinase from the Thrombolysis in Myocardial infarction (TIMI Phase I) trial*. *Circulation* 1987;75:817-29.
- 51) Kalbfleisch H, Hort W. *Quantitative on the size of coronary artery supplying areas postmortem*. *Am H J* 1977;94:183-8.
- 52) Hamby RI, Schwartz A. *Reappraisal of the functional significance of the coronary collateral circulation*. *Am J Cardiol* 1980;38:304-9.
- 53) Goldberg HL, Goldstein J, Borer JS, Collins MB, Moses JW, Ellis G. *Determination of angiographic appearance of coronary collateral vessels: the importance of supplying and recipient arteries*. *Am J Cardiol* 1983;51:434-9.
- 54) Seiler C, Fleisch M, Garachemani A, Meier B. *Coronary collateral quantitation with coronary artery disease using intravascular flow velocity or pressure measurements*. *J Am Coll Cardiol* 1998;32:1272-9.